Logistics/Supply Chain & Energy Storage

Lessons learned from Inventory Management and Flexible Production

Mohsen Jafari, Ph.D.
Niloofar Mirhosseini, P.h.D. candidate
Rutgers University
Center for Advanced Infrastructure & Transportation (CAIT)

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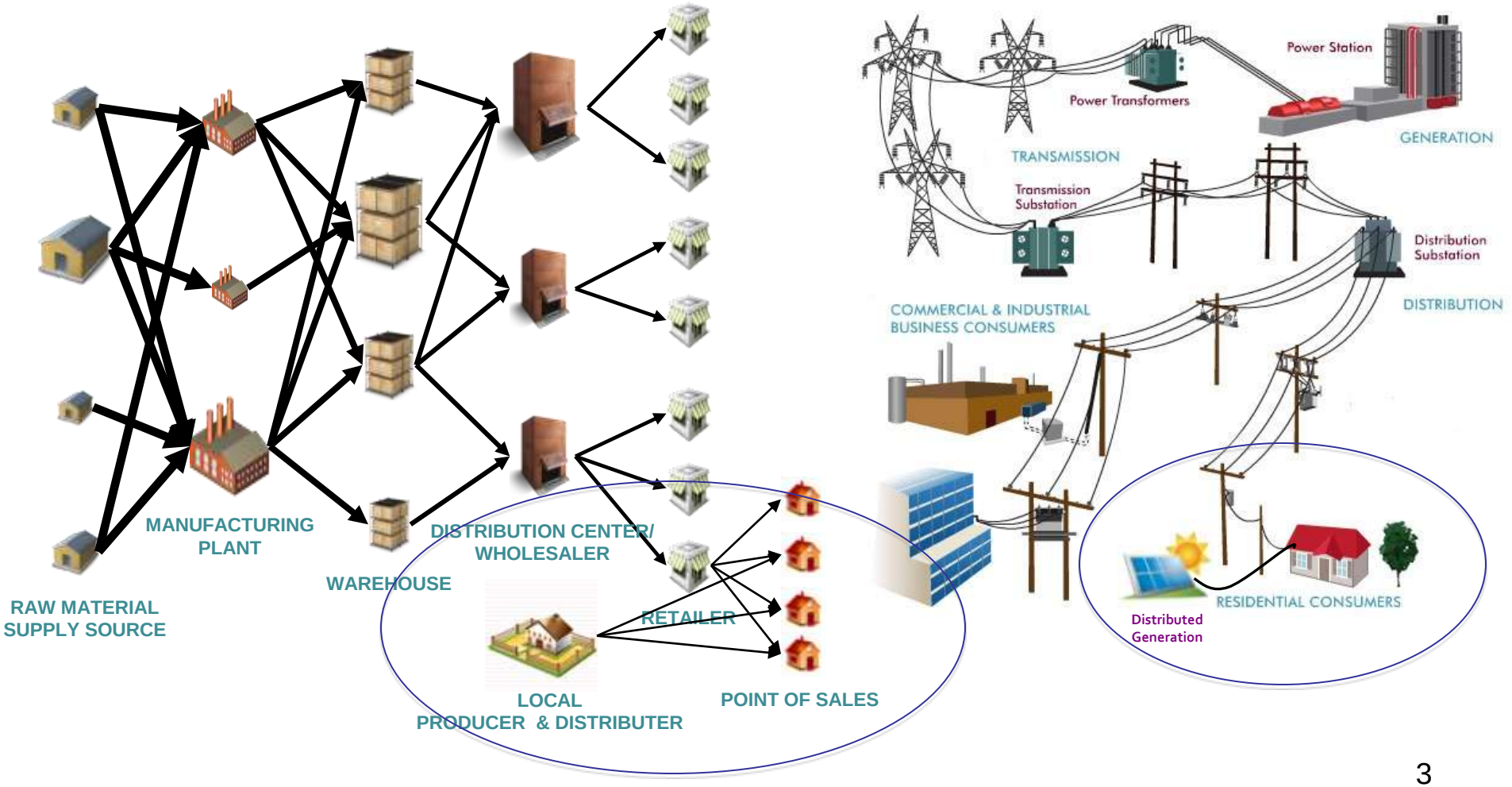
Outline

- Drawing parallels in grand scale
- Demand Management
- Risk Management
- Inventory Management
- Flexible Production systems
- Drawing parallels in more details
- What is next?

Drawing parallels – Grand scale

How to manage demand & risks?



Demand Management

- Generate demand
  - Push system (from source to sink)
  - Pull system (from sink to source)
  - Just in Time (JIT) System
- Meet demand
  - Kanban control for inter-process regulation
  - Line balancing for flow regulation
  - Manufacturing Execution Systems (MES)
    - Day-ahead scheduling
    - Hourly scheduling
  - Manufacturing/Material Requirements Planning (MRP)
  - Enterprise Resource Planning (ERP)
    - Master scheduling
    - Resource mapping

Risk Management

- Demand Uncertainty
  - Storage mitigates demand surge risk
- Transport & Delivery Delays
  - Storage near delivery / customer mitigates risk
- Lost Sales & Contractual Penalties for Delays
  - Curtailment and Liquidated Damages
- Inventory carrying costs
- Inventory devaluation/depreciation
  - Perishable / seasonable goods; fashion shifts; price erosion
- Balancing Risks vs Cost of Mitigation

Drawing Parallels

	Logistics/SC	Power
Demand management	Kanban	Dispatching
	Line balancing	Energy regulation
	Manufacturing Execution System (MES)	Wholesale market design
Demand generation	JIT, push or pull	Used to be JIT, moving towards push+pull
Business risks	Retailer lost business	Load curtailment
Risks and mitigation	Safety stock	Spinning reserve
	Lead time	Delays/lost load due to wrong renewable forecast
	Inventory Buffer	Storage
	Dynamic rerouting	Dynamic switching

A closer look @ parallels

Logistics/Supply Chain

- Flexible routing for reliability
- Long term supply contracts & short term case by case
- Supplier Redundancy

Power & Energy

- Inherent transmission network; switching in distribution
- PPAs, DA Market, Real Time / Spot Market
- Capacity Margin & Reserves

- **Location, capacity & charge/discharging control of Inventory/storage**

Inventory management

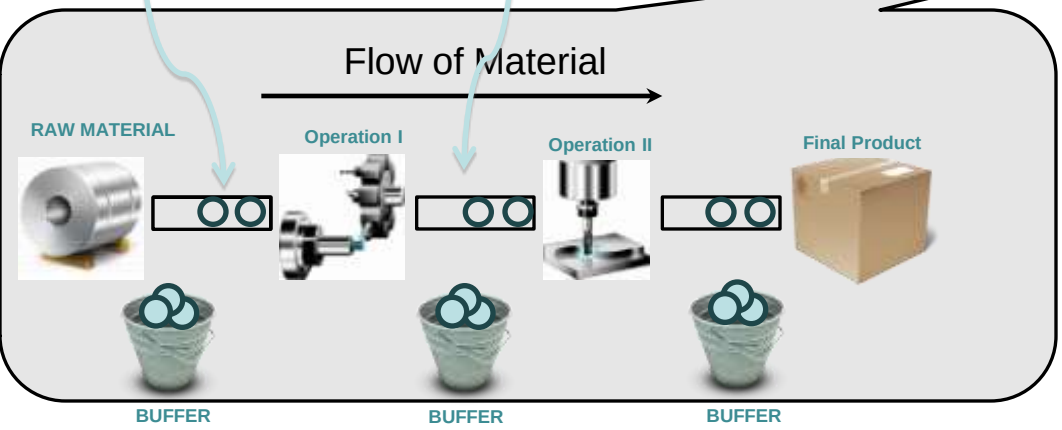
- **Why?**
  - Inter-process regulations; to dampen process variations & drifts
  - Safety stock to reduce shortage risks
  - Warehouse to store finished goods and and raw materials
  - Arbitrage (for raw materials and finished goods)
  - Higher performance and throughput
- **How?**
  - Continuous monitoring & control (charging) according to EOQ or other control policies; discharge can be continuous or discrete;
  - Periodic monitoring & control according to EQO or other policies; discharge can be continuous or discrete;
  - Single period (Newsboy problem)
- **Where and how big?**
  - **Location, Capacity & charge/discharging control of Inventory/storage**

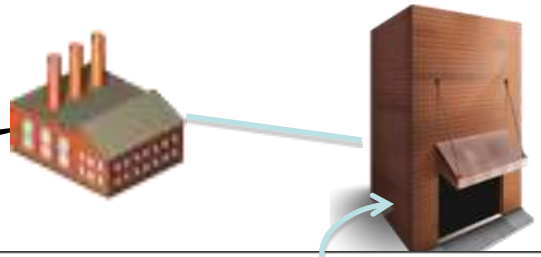
Examples (why & how?)

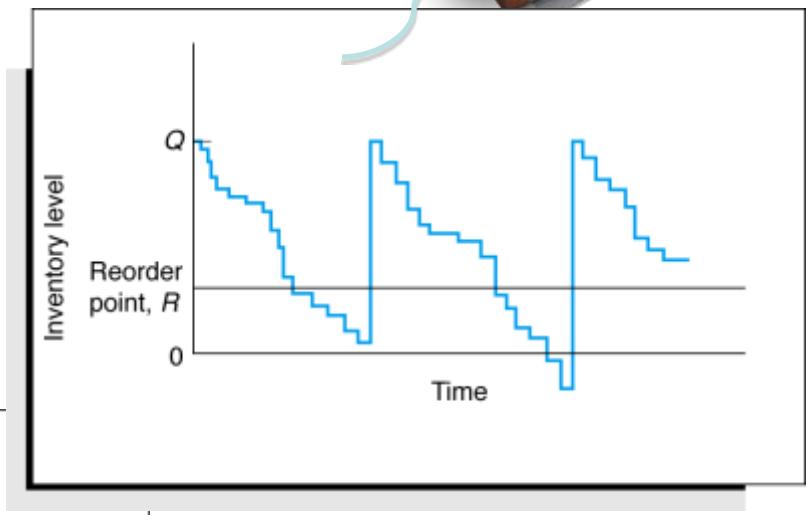
WIP

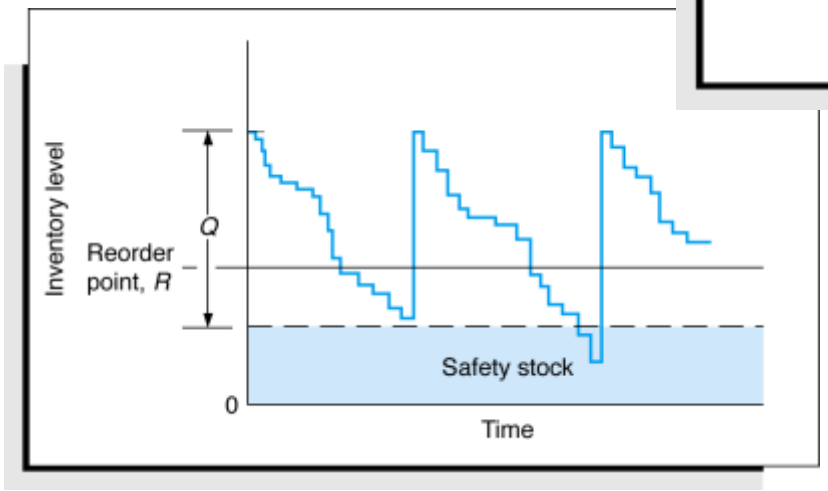
blockage

starvation







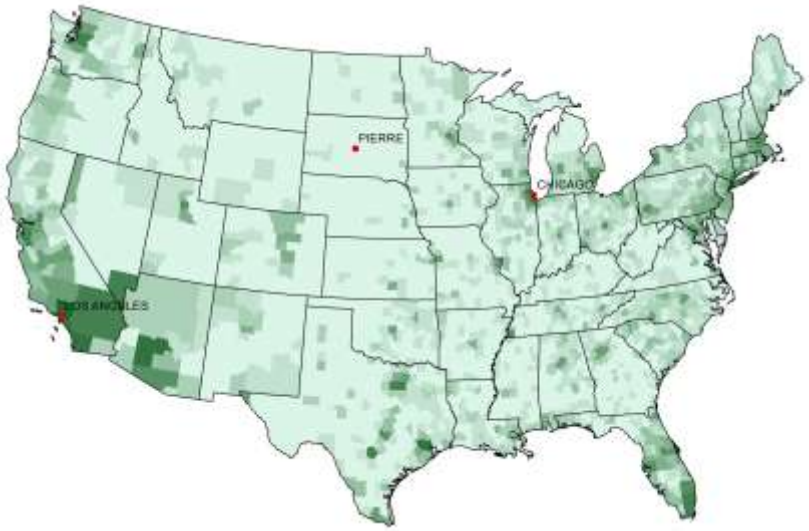


Safety Stock

Location & Capacity (1)

- Proximity to population centers matter
- Location of distribution center makes a difference;

- Transportation cost in terms of person-miles (PM) for 1 distribution center in:
  - LA: 557,912 million
  - Chicago: 294,092 million
  - Pierre: 326,247 million



Location and Capacity (2)

- 2DCs: 195,986 million PM

Location & Capacity (3)

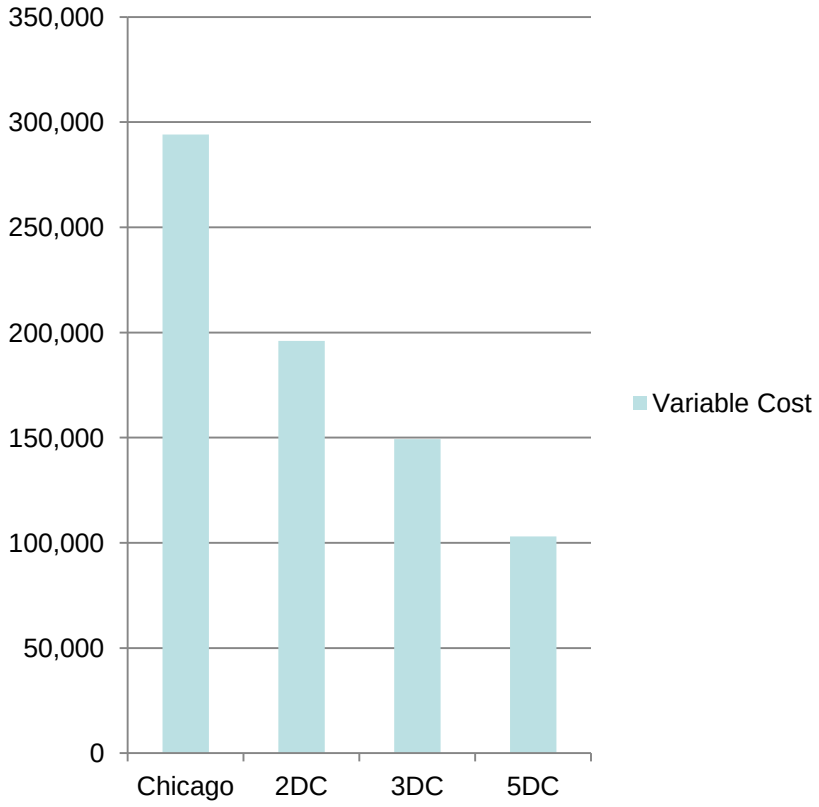
- 2DCs: 195,986 million PM
- 3DCs: 149,243 million PM

Location & Capacity (4)

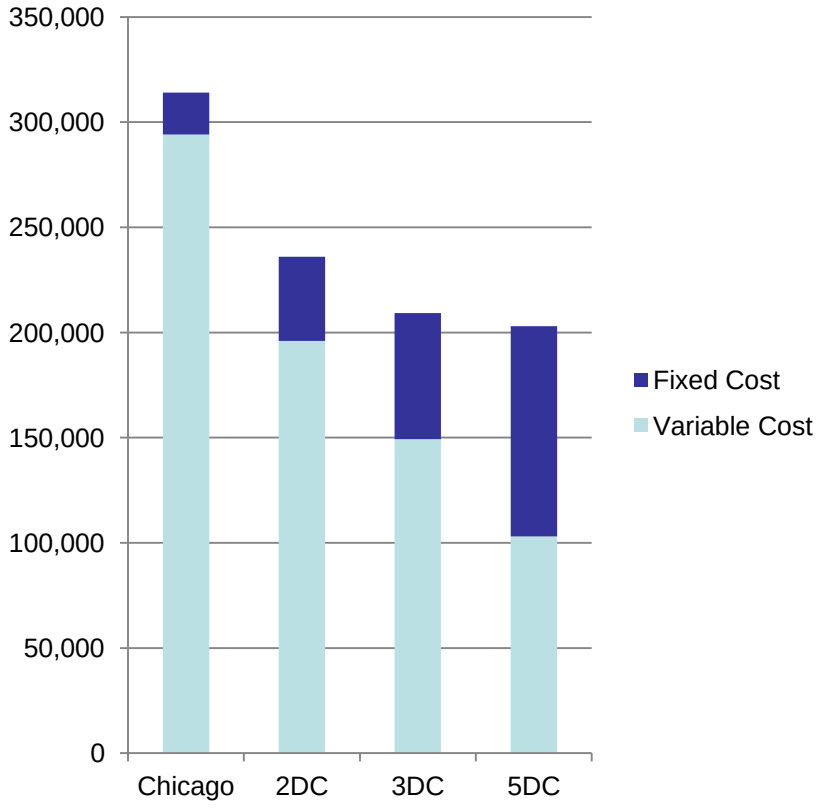
- 2DCs: 195,986 million PM
- 3DCs: 149,243 million PM
- 5DCs: 103,003 million PM

Cost of inventory vs location/capacity

Variable Cost Only



Fixed and Variable Cost



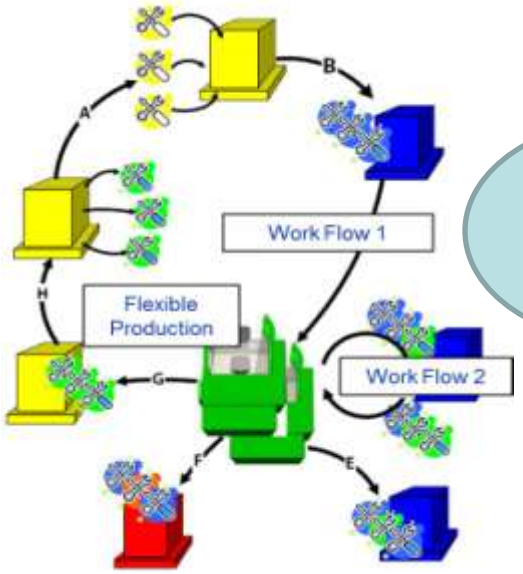
More parallels – inventory vs storage

Terminologies	Inventory control	Storage control
Demand	Quantity demanded per unit of time	Demand(t) = max {0,load(t) - transformer capacity}
Shortage cost ($/unsatisfied demand)	Cost of lost sales	Penalty due to loss of load
Setup cost ($/charge)	Component of ordering cost which does not vary with order amount	Battery capital cost per cycle
Proportional order cost ($/unit)	Cost per unit	Average cost to charge
Lead time (Hours)	Time interval between placing an order and receiving it	Battery duration
Flow capacity	Transportation capacity	Transformer capacity (for upgrade deferral)

Flexible Production System

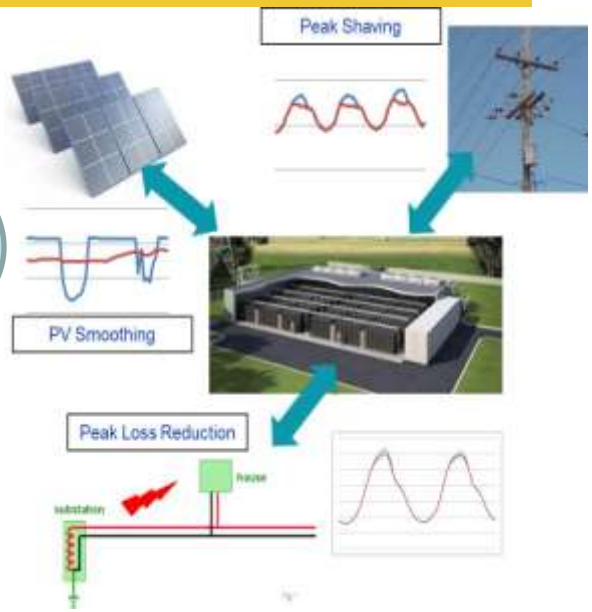
- Flexibility to react to planned or unplanned (random) changes & failures;
  - *Machine flexibility*
    - Ability to produce new product types
    - Ability to change the order of operations executed on a part
  - *Routing flexibility*
    - Ability to use multiple machines to perform the same operation on a part
    - Ability to absorb large-scale changes in volume, capacity, or functionality
  - *Small to medium size production batches*
  - *Significantly small set up times and costs*

Drawing Parallels – part mix ratio & multi use storage



Part Mix Ratio

Energy Storage Multi-use



Problems	Flexible Manufacturing System	Energy Storage
Design	Capacity of material handling system, buffer size	Storage sizing for multiple-use
Planning	Short term (one day): Parts mix ratio Allocation of pallets and fixtures Assignment of operations	Day ahead commitment level for different applications
Scheduling	On-day: Optimal sequence of inputs Optimal machine output	Optimal control of charging and discharging of storage

Lessons learned

- It works.
- Very mature with many simple and intelligent solutions (e.g., EOQ and r&R policy).
- Commercial solution packages for intelligent inventory management across large networks of suppliers, distribution centers, and points of sales.
- Uses demand forecasts but is usually robust to random noises.
- System intelligence is the key!

What is next?

- Multi-objective use of storage
  - Substation upgrade deferral
  - Substation transformer life extension
  - Loss reduction
- Optimal storage size and location
- Doing better with a smaller storage unit

- Reduce Capital Costs and cycle Losses
- Reduce Risk of Premature Failure
- Better manage capacity expansion deferral (substation)